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A new species of *Crocidura* (Insectivora: Soricidae) recovered from owl pellets in Thailand

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SYNOPSIS. A new species of *Crocidura* (white-toothed shrew) is described from owl pellets from Loei Province, Thailand. The craniodental morphology is compared with that of similar sized species of *Crocidura* recorded from Thailand.

INTRODUCTION

A recent survey of bat roosts and owl pellets in Thailand by one of us (ALS) and Mark F Robinson has increased knowledge of the small mammal fauna of the area. Contained in the owl pellets were skulls of 38 species of small mammals, including an unknown species of *Crocidura*. This undescribed species has sufficiently distinctive cranial and dental characters to warrant its description on the basis of these features alone, although the external characters remain unknown.

MATERIALS AND METHODS

Regurgitated pellets were collected from roosting sites of barn owls (*Tyto alba* [Scopoli, 1769]) at several localities in Thailand. The pellets were dissected and the contents, usually incomplete crania and mandibles, were identified as far as possible in the field. Voucher specimens were sent to The Natural History Museum for confirmation of identification. Included among these specimens was a series of *Crocidura* which was proving difficult to identify and was thought to include two species, *C. attenuata* Milne-Edwards, 1872 and *C. fuliginosa* (Blyth, 1855).

Measurements, in millimetres, were taken using dial calipers or a micrometer eyepiece and measuring stage on a microscope. Cranial and dental nomenclature follows that of Meester (1963), Mills (1966), Swindler (1976) and Butler & Greenwood (1979). Abbreviations for the dental nomenclature are given in the text.

RESULTS

Crocidura hilliana sp. nov.

HOLOTYPE. BM(NH)1994.90, collector's number 467. Cranium with damaged braincase, left mandibular ramus, complete maxillary and mandibular dentition. Extracted from an owl pellet from a roost at Wat Tham Maho Lan, Ban Nong Hin, 48 km south of Loei, Loei Province, northeastern Thailand, 17°06′N 101°53′E, altitude 575m.

PARATYPES. Eighteen specimens of crania with mandibles and thirteen specimens of crania only, all from owl pellets at the same locality as the holotype. Three specimens of crania with mandibles and five specimens of crania only from Wat Tham Pha Phu, 7 km north of Loei, Loei Province, 17°34′N 101°42′E, altitude 542m.

Diagnosis

Zygomatic process of maxilla broad and angular, interorbital region narrow; coronoid process broad and deep. Upper and lower first incisors robust, first upper unicuspid large and broad relative to the other unicuspids, talonid of the third lower molar (M_3) reduced to a single cusp.

Description

Overlapping in cranial size with medium to large specimens of *Crocidura attenuata* and smaller specimens of *C. fuliginosa* but differing from both species in proportions (see Table 1 and Figs 1–6). Cranium and mandible robust; cranium angular in appearance, especially in dorsal view. The rostrum is moderately deep and obliquely sloping anteriorly; the maxillary region is broad, the zygomatic process of the maxilla is broad and angular; the interorbital region is long and narrow, its width increasing only slightly from anterior to posterior; the zygomatic plate is positioned above the first upper molar (M^1) and the anterior of the second upper molar (M^2), its posterior face is semi-circular and deeper than the anterior face; the braincase is angular, with pronounced angular superior articular facets in dorsal view, a squamosal crest is present and lambdoid crests are well developed, meeting at an acute angle at the midline. The horizontal ramus of the mandible is moderately robust; the coronoid process is broad and deep (see Fig. 4); the ascending ramus is long and low; the condyle is nearly as broad or broader than deep (ratio of

Fig. 1 Dorsal view of cranium from left to right of *C. attenuata* BM(NH)1911.9.8.26, *C. hilliana* BM(NH)1994.113 and *C. fuliginosa* BM(NH)1933.4.1.183.

condyle width to height 91.2–113.3), the postero-internal ramal fossa has a broad base and is approximately as broad as deep; the mental foramen is positioned below the anterior part of the first lower molar (M_1).

The dentition is illustrated in Figs 2–6. The first upper incisor (I^1) is robust, slightly proodont with well developed posterolingual and posterobuccal cingula; the upper unicuspids are overlapping and crowded; the first upper unicuspid (Un^1) is large and broad in comparison with the other unicuspids, its breadth is equal to or greater than the distance between the two first unicuspids and this tooth is more than two thirds the height of I^1 and P^4; the second and third unicuspids (Un^2 and Un^3) are subequal in size; the upper premolar (P^4) has a moderately small parastyle and robust metacone; the first and second upper molars (M^1 and M^2) show no significant distinguishing features; the third upper molar (M^3) is short and slender with a slightly compressed lingual basin. The first lower incisor (I_1) is robust, long, deep and curved, and the anterolingual ridge extends for *circa* three quarters of the length of the tooth, diverging from the ventral border, the posterior border of I_1 lies below the middle of the lower premolar (P_4); two thirds of the second lower incisor (I_2) are in contact with I_1 and one third of the tooth is overlapped by P_4; the postentoconid ledge is very narrow in the first lower molar (M_1) and yet more reduced in the second lower molar (M_2); the talonid of the third lower molar (M_3) is reduced to a single cusp.

Etymology

This species is named in honour of John Edwards Hill, who taught one of the authors (PDJ) the basics of mammalogy and who also provided invaluable help in the identification of some of the skull fragments of bats found during the survey.

Comparison with other species

Five species of *Crocidura* have been recorded from Thailand (Lekagul & McNeely, 1977, Davison, 1984): *C. fuliginosa* (including *C. dracula* Thomas, 1912 listed as a separate species by Lekagul and McNeely), *C. attenuata*, *C. pullata vorax* Allen, 1923 (listed as *C. russula vorax*), *C. horsfieldii indochinensis* Robinson & Kloss, 1922 and *C. monticola* Peters, 1870. *Crocidura hilliana* is separated from most specimens of *C. fuliginosa dracula* by its smaller size (see Table 1), while it is considerably larger than *C. p. vorax* (condylobasal length <17.5), *C. horsfieldii* (condyloincisive length <17.9, data taken from Heaney & Timm (1983) for specimens from Vietnam) or *C. monticola* (condylobasal length <17.4).

Crocidura hilliana falls at the middle to upper part of the cranial size range of *C. attenuata* and the lower part of the size

Fig. 2 Ventral view of cranium from left to right of *C. attenuata* BM(NH)1911.9.8.26, *C. hilliana* BM(NH)1994.113 and *C. fuliginosa* BM(NH)1933.4.1.183.

range of *C. fuliginosa* (see Table 1). It is readily distinguished from both species by its robust, angular cranium, in which the maxillary region is broad, the interorbital region narrow and the anterior part of the braincase markedly angular (see Figs 1–3). In contrast, both *C. attenuata* and *C. fuliginosa* have a proportionally narrower maxillary region, broader interorbital region increasing noticeably from anterior to posterior and a more rounded braincase that is evidently broader than the maxillary region. Lambdoid crests are more or less well developed in both *C. hilliana* and *C. fuliginosa*, but they meet at an acute angle at the midline in *C. hilliana* and a shallower angle in *C. fuliginosa*; lambdoid crests are less developed in *C. attenuata* and meet at a shallow angle. Squamosal crests are absent or ill defined in *C. attenuata*, poorly to moderately defined in *C. fuliginosa* but well-marked in *C. hilliana*. The mandible of *C. hilliana* is considerably more robust than that of either of the other two species (see Fig. 4). The horizontal ramus of the mandible of *C. attenuata* is more slender than that of *C. hilliana*, with a sinuous ventral border; the coronoid process is considerably narrower and shallower; the ascending ramus is higher and the condyle is higher than broad (ratio of condyle width to height 75.0–93.3). The horizontal ramus of the mandible of *C. fuliginosa* is longer yet shallower than that of *C. hilliana*, with a narrower, less robust coronoid process and, as in *C. attenuata* the condyle is higher than broad (ratio of condyle width to height 77.8–93.3). The mental foramen lies below the posterior part of P_4 in *C. attenuata* and *C. fuliginosa* but below the anterior of M_1 in *C. hilliana*. Dentally the most obvious differences between *C. hilliana* and the other two species is the comparatively large anterior dentition (I^1, Un^1 and I_1) relative to the rest of the teeth, in combination with the narrow M^3 and the reduced M_3 of *C. hilliana*, differing considerably from the condition in either *C. attenuata* or *C. fuliginosa* (see Table 1 and Figs 2–6).

In detail the dentition of *C. attenuata* differs in the following aspects from that of *C. hilliana*: I^1 is slender and orthodont, the posterolingual cingulum is narrow, Un^1 is moderate in size and the distance between the two first upper unicuspids is greater than the breadth of Un^1, Un^2 is smaller than Un^1 and Un^3, and the unicuspids overlap only slightly so that the rostrum is moderately long in appearance; the parastyle of P^4 is moderately well developed. M^3 is variable in different populations of *C. attenuata*; it is medium sized in Indian and Burmese populations and thus readily distinguished from *C. hilliana*, and although only narrower on average in the Chinese populations of *C. attenuata*, nevertheless, the lingual basin is less compressed than in *C. hilliana*. The first lower incisor of *C. attenuata* is moderately slender, straighter and more procumbent than that of *C. hilliana*; the anterolingual ridge extends for two thirds the length of the tooth and is subparallel to the ventral border of the tooth; the posterior border of I_1 lies below the posterior part of I_2; less

Table 1 A comparison of species of *Crocidura* occuring in Thailand and nearby countries.

	C. hilliana Thailand	*C. attenuata* China	India	*C. fuliginosa* Thailand	Vietnam	China
Condylobasal length	21.0–23.5	19.8–20.7	19.7–21.6	22.0, 22.8	21.3–23.4	21.6–22.7
mean	22.20	20.20	20.23		22.58	22.20
SD	0.68	0.38	0.54		0.51	0.47
n	16	8	10	2	15	4
Upper toothrow length	8.8–10.2	8.7–9.4	8.7–9.8	10.1–10.8	9.8–10.8	9.7–10.7
mean	9.45	9.00	9.12	10.42	10.25	10.17
SD	0.35	0.23	0.29	0.29	0.27	0.35
n	37	12	17	5	24	11
Maxillary breadth at level of M^2	6.0–7.2	5.7–6.4	5.8–6.5	6.6–7.0	6.7–7.3	6.7–7.2
mean	6.57	6.14	6.08	6.72	6.96	6.91
SD	0.30	0.21	0.19	0.16	0.15	0.17
n	38	12	17	5	23	11
Interorbital breadth	3.8–4.6	4.2–4.8	4.2–4.7	4.4–4.7	4.7–5.3	4.7–5.2
mean	4.27	4.46	4.39	4.55	4.93	4.93
SD	0.21	0.19	0.12	0.13	0.13	0.19
n	38	10	15	4	22	8
Braincase breadth	8.9–10.0	8.5–9.5	8.7–9.8	9.9–10.1	9.8–10.7	9.9–10.6
mean	9.56	9.09	9.08	10.00	10.24	10.14
SD	0.36	0.34	0.33	0.12	0.24	0.26
n	16	9	11	3	18	5
Mandible length excluding I_1	10.7–12.7	10.0–11.5	10.1–11.2	11.8–12.4	11.7–13.1	11.5–12.7
mean	11.35	10.71	10.62	12.09	12.36	12.06
SD	0.55	0.46	0.42	0.24	0.35	0.41
n	21	13	17	8	26	11
Mandible height	5.2–6.3	4.4–5.1	4.5–5.2	5.2–5.8	5.4–5.9	5.2–6.0
mean	5.78	4.81	4.65	5.54	5.61	5.62
SD	0.28	0.22	0.21	0.18	0.16	0.25
n	21	13	17	9	26	9
Interorbital breadth: maxillary breadth	60.5–70.5	68.8–77.7	68.3–77.6	65.7–69.7	67.1–75.4	68.9–73.2
mean	65.00	72.36	72.40	67.43	70.86	71.09
SD	2.44	2.98	2.48	1.66	2.26	1.55
n	38	10	15	4	22	8
Length of M^3: upper toothrow length	5.2–7.0	6.4–6.9	7.1–8.0	6.8–7.9	6.6–8.0	6.9–8.0
mean	6.12	6.67	7.50	7.48	7.28	7.34
SD	0.51	0.16	0.28	0.42	0.42	0.35
n	34	12	17	5	24	10

than half of I_2 is in contact with I_1 and I_2 is one quarter overlapped by P_4; a postentoconid ledge is present in M_1 and M_2; the talonid of M_3 is relatively complete and an entoconid, entoconid ridge and talonid basin are present.

Crocidura fuliginosa differs from *C. hilliana* in having a moderately slender, orth-opisthodont I^1 with a smaller although well developed posterolingual cingulum; Un^1 is moderate in size (c half the height of I^1 and P^4); in contrast to the condition in *C. attenuata*, Un^2 is only slightly smaller than Un^1 and Un^3; the lingual region of P^4 is characteristic in shape; the mesostyle of M^2 is divided into two stylar cusps (see Ruedi, in press) unlike either of the other species; M^3 is medium in size and the lingual basin is not compressed. The mandibular dentition is similar to that of *C. attenuata*. In particular it is readily distinguished from *C. hilliana* by the less robust, straighter, more procumbent first lower incisor; slightly over half of I_2 is in contact with I_1; the talonid of M_3 is not reduced and an entoconid, entoconid ridge and talonid basin are present.

DISCUSSION

It is known from the study of barn owl pellets in the British Isles and Africa (Glue, 1967; Andrews 1990) that prey skeletal elements are subject to little breakage or digestion, contrary to the case for pellets of some other avian predators. Certainly there is a degree of damage to all of the crania in the current sample, none of which are intact. Crania and associated mandibles occur in 48%; a few specimens are nearly complete showing only minimal damage to the braincase, although the braincase is broken or absent in most specimens. The toothrows are complete in 87% of specimens, although the teeth may be loose in their sockets, with tooth loss occuring generally at the terminal molar or unicuspid loci. There is little evidence of digestive erosion of crania or teeth. It has therefore proved possible to take most of the standard cranial measurements on sufficient of the recovered crania and mandibles to obtain significant data on size variation. Similarly, the dentition is well preserved so that diagnostic characters are readily observed and allowing the samples to be aged. Shrews of the genus *Crocidura* show very rapid dental maturation as nestlings, teeth are fully erupted shortly after leaving the nest. The dental ages appearing in these samples include fully erupted dentitions with no sign of tooth wear, probably representing juvenile or subadult specimens; dentitions showing slight to moderate wear, representing adults; dentitions showing extreme wear, representing old adults.

Fig. 3 Lateral view of cranium from top of *C. attenuata* BM(NH)1911.9.8.26, *C. hilliana* BM(NH)1994.113 and *C. fuliginosa* BM(NH)1933.4.1.183.

There have been few systematic collections of the small mammal fauna in Thailand, which in consequence remains comparatively little known; in particular the shrews are poorly documented. *Crocidura fuliginosa* was recorded from peninsular Thailand by Bonhote (1903), Kloss (1917) [as *C. aagaardii*], Robinson & Kloss (1923) and Hill (1960) [probably referring to the same specimen as Robinson & Kloss (1923)], and from Koh Samui off the east coast of peninsular Thailand by Robinson & Kloss (1914) [as *C. negligens*]. The inclusion in this taxon of two chromosomally distinct but morphologically cryptic species in Malaysia was discovered recently by Ruedi *et al.* (1990). Ruedi (in press) has attempted to correlate morphological features with these chromosomal forms, in order to assign specific names to them, reserving the name *C. fuliginosa* for those specimens with chromosomes 2n = 40, Fundamental Number 56 and ascribing the other species, with polymorphic chromosomes of 2n = 38–40, to *C. malayana* Robinson & Kloss, 1911. Regrettably, examination of Malaysian specimens in the collection of the Natural History Museum fails to confirm the supposedly clearcut morphological distinction, with some specimens exhibiting a mixture of the characters listed by Ruedi, so negating the use of these morphological criteria. *Crocidura fuliginosa* is a widely distributed species, occuring from Burma in the west to China in the east and southwards to Indonesia, including a number of named forms, whose taxonomic status has been the subject of considerable discussion (Medway, 1965, 1977; Jenkins, 1976, 1982; Heaney & Timm, 1983; Corbet & Hill, 1992). The presence of cryptic species in Malaysia, emphasises the lack of understanding of the status of *C. fuliginosa*, suggesting that it requires further revision and might be more appropriately considered as a species complex. There are few records of this species from regions other than peninsular Thailand, apart from that of Lekagul & McNeely (1977) from Chiengmai, or Chiang Mai, northwest Thailand (as *C. fuliginosa* and *C. dracula*). Furthermore, there are no specimens of *C. fuliginosa* from Thailand, other than peninsular Thailand, in the collection of The Natural History Museum, while in the collection of the American Museum of Natural History there are single specimens from Nakhon Nayok, Khao Yai National Park and Nakhon Ratchasima, central Thailand, plus an unconfirmed specimen from Umphang, western Thailand. In the current survey, *C. fuliginosa* was identified from prey remains of the carnivorous bat, *Megaderma lyra* E. Geoffroy, 1810 collected at Thung Yai–Huai Kha Khaeng Wildlife Sanctuary, western Thailand; however there are only a few fragmentary specimens, dubiously attributed to this species, among the owl pellets from Loei Province. There are similarly few records of *C. attenuata* from Thailand; Lekagul & McNeely (1977) listed this species from Nakhon Phanom and Udon in the northeast, and Chiang Mai, northwest Thailand. There was no evidence

Fig. 4 Lateral view of mandible from top of *C. attenuata* BM(NH)1911.9.8.26, *C. hilliana* BM(NH)1994.90 and *C. fuliginosa* BM(NH)1933.4.1.183.

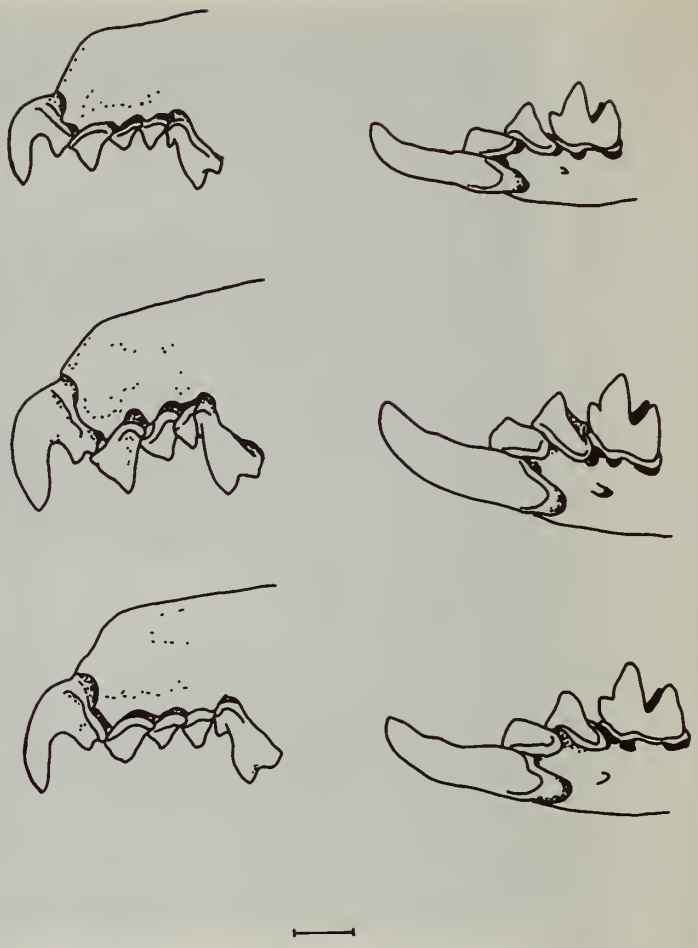

Fig. 5 Lateral view of left anterior dentition. Left: upper toothrow (I^1 to P^4); right: lower toothrow (I_1 to P_4). Top: *C. attenuata* BM(NH)1911.9.8.26; middle: *C. hilliana* BM(NH)1994.119 upper toothrow, BM(NH)1994.118 lower toothrow; bottom: *C. fuliginosa* BM(NH)1933.4.1.178. Scale 1 mm.

of *C. attenuata* either amongst the owl pellet remains from Loei Province or from remains found at *M. lyra* roosts in Thung Yai–Huai Kha Khaeng. It is therefore uncertain if *C. hilliana* is sympatric with either *C. fuliginosa* or *C. attenuata*.

Crocidura hilliana does, however, occur sympatrically with a smaller species of *Crocidura* which proved difficult to determine from the fragmentary skulls in the owl pellets. Allen & Coolidge (1940) collected *C. vorax* (currently grouped with *C. pullata* Miller, 1911 from the Himalayas, see Hutterer, 1993) from northwestern Thailand, while a specimen from Lat Bua Kao, mainland Thailand, attributed to *C. fuliginosa* by Kloss (1919) is also an example of *C. p. vorax*. Several skulls attributable to this species were found in the owl pellets from Loei, while a good series was recovered from the *M. lyra* prey remains from Thung Yai–Huai Kha Khaeng, where an additional skull was found in the faeces of a large carnivore. The only other species of *Crocidura* listed by Lekagul & McNeely (1977) from mainland Thailand was *C. horsfieldii indochinensis* from Chiang Mai and Khao Yai National Park . Most recently, Davison (1984), recorded *C. monticola* from penisular Thailand. Neither of the last two species mentioned above were identified from either area, although pellets from Loei Province contained another shrew *Suncus etruscus* (Savi, 1822), plus a variety of rodent and bat species.

Since there has been so little systematic collection in Thailand, it is impossible to make categoric statements about the new species, however it seems likely that it is relatively localised in its distribution. Even in areas where collecting

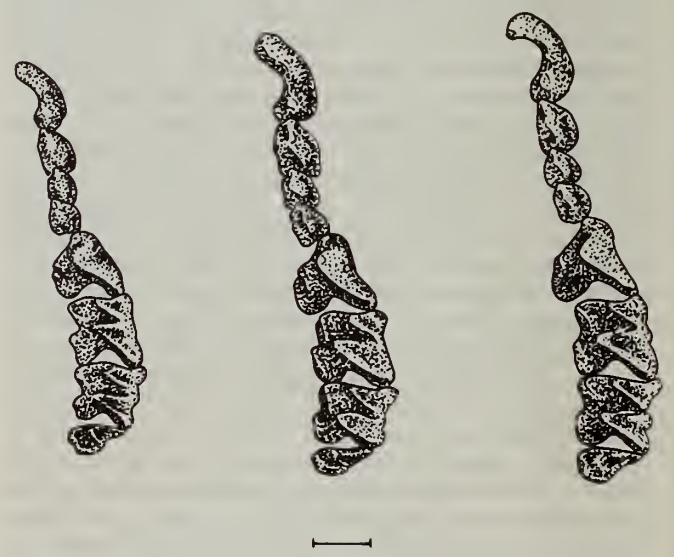

Fig. 6 Occlusal view of left upper toothrow from left to right of *C. attenuata* BM(NH)1911.9.8.26, *C. hilliana* BM(NH)1994.121 and *C. fuliginosa* BM(NH)1933.4.1.178. Scale 1 mm.

efforts have been more stringent, shrews are frequently difficult to trap, perhaps giving a false impression of their rarity as faunal components. The discovery of this new species of shrew, apparently present as a sufficiently large population to form an important and regular part of the diet of the resident owls, is therefore not so surprising as it might first appear. Because of the nature of the specimens, even less information than usual is known about the ecology of the new species, although some implications may be drawn from knowledge of the ecology and behaviour of the owls. The barn owl roosting sites of both collecting localities are caves in limestone outcrops in or near temple grounds, surrounded by bamboo and deciduous trees. Individual roost sites at Wat Tham Maho Lan are generally within 0.5 km of cultivated maize fields, while those at Wat Tham Pha Phu are within 1 km of rice and cassava fields. The home range of barn owls in the British Isles and Africa is generally 1–2.5 km, rarely up to 3 km (Bunn *et al.* 1982; Andrews, 1990). Because of this small hunting range, it may be inferred that this habitat which extends for some distance around the roosting site is also the habitat for the shrews on which they prey. Barn owls are nocturnal and crepuscular in their hunting behaviour, the implication being that the shrews are active for at least a proportion of the same activity period.

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